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LEVELING IN THE U.S.S.R.

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SUMMARY

The vertical-control net in the U.S.S.R. developed very slowly during the period from 1847 to 1917 and little, if any, of that leveling was better than third-order. Beginning in 1919 a serious attempt was made to do leveling of modern quality. Progress was slow at first, instrumental equipment was of inferior quality, observing routines were unduly complicated and the area to be covered was very great.

However, considerable progress was made and up to World War II about 70,000 miles of First- and Second-order leveling had been completed.

Following World War II there was a real attempt to increase both accuracy and production. Instrumental equipment has been improved until it now compares favorably with modern European equipment. By 1946 preparations were being made for a general adjustment of the leveling net with elevations based on a sea-level datum at Kronshtadt, except the leveling eastward at Novosibirsk which, for the time being at least, is based on mean sea level at Vladivostok.

Probably owing to the great size of the Soviet territory, the circuits are larger than in the U.S.A. and bench marks do not seem to have been established as frequently along the lines of leveling.

However, although their vertical control net is not now as complete as ours, the prospects are that because of their great interest in control leveling, the improvement of their instrumental equipment, and the constantly increasing supply of trained personnel, it will not be long before their vertical-control net, especially in European U.S.S.R. will compare very favorably with that in the U.S.A.

I. ANALYSIS OF SOVIET METHODS, PROCEDURES AND INSTRUMENTATION

A. HISTORICAL SUMMARY

The history of leveling in the U.S.S.R. seems to have followed about the same general pattern as in many other countries, including the U.S.A. From a small beginning at or near the middle of the 19th century the leveling net developed slowly with no very great acceleration of pace until after 1917. Instrumental equipment in the beginning was, according to modern standards, quite crude. Rabinovich (1) states that spirit leveling was undertaken as early as 1847 but that even as late as 1873-74, when the Korpus Voyennykh Topografov (Corps of Military Topographers -- K.V.T.) leveled between Moscow and Petersburg, the instruments used had a magnification of only 6 to 8 diameters. From 1875 to 1877 a level having a magnification of 13 or 14 diameters was used. The leveling of these three years showed a mean systematic error of $\pm$ 0.9 mm. per km., and a mean accidental error of $\pm$ 6.2 mm. per km. Such leveling would not qualify under the present specifications as 3rd-order. By 1881, when a rather ambitious program was planned, the levels in use had magnifications of approximately 40 diameters. These magnifications have not been increased beyond 44X since that time.

The project planned about 1881 had four major objectives:

1. A line between the Baltic and Black Seas,
2. Lines along railways near the parallels of 47° and 52° north latitude,
3. Lines along the shores of the Baltic and Black Seas and the Sea of Azov to connect with tide stations, and
4. Along railways to the western border to connect with the Middle-European leveling net.

The results of the leveling from 1881 to 1893 were published in 1894. At this time the rate of progress began to increase. In 1893 the leveling totaled 13,000 km. From 1893 to 1917 the KVT completed 32,500 km., of "precise" leveling with a mean error of ± 4.5 mm. per km. This was a considerable improvement in accuracy, but still not up to modern standards.

During 1913 the KVT undertook "leveling of high precision" according to standards prescribed by the International Geodetic Association which limited the systematic error to ± 0.3 mm. per km., and the accidental error to ± 1.5 mm. per km. However, up to 1917, only one line of "leveling of high precision" had been completed; the line from Petersburg to the Black Sea.

Using the term "precise leveling" as the equivalent of our "2nd-order leveling" and "leveling of high precision" as the equivalent of our "1st-order leveling", the Russians had in 1917 a total of 45,500 km. of "precise" of "2nd-order" leveling.

During a 25-year period following the Revolution, the Main Administration of Geodesy and Cartography (GUGK) completed a total of 116,000 km. of leveling of 1st- or 2nd-order accuracy.

The leveling from 1847 to 1917 (2) was done by the KVT. The Revolution caused the suspension of leveling operations until March, 1919 when the VGU (Vyssheye Geodezicheskoye Upravleniye = Higher Geodetic Administration) undertook leveling of high precision. In September, 1926, the VGU was reorganized and became the Geodezicheskiy Komitet (Geodetic Committee). In 1928, it became the General Geodetic Committee of the VSNKh (Higher Council of National Economy). In 1930 the General Geodetic Committee was reorganized and became the General Geodetic Administration. Then, in 1933, the General Geodetic Administration was united with the Main Geological Administration and the name became "Main Geological-Hydro-Geodetic Administration" (Glavnoye Geologo-Gidro-Geodezicheskoye Upravleniye - GGGGU). This organization was given the supervision of geodetic work. In May, 1934, this supervision was transferred to the Interdepartmental Geodetic Council. The Government Geodetic Service, by resolution of the Council of Commissars of the U.S.S.R. of September 14, 1938, was made directly subordinate to the Council of Commissars and later to the Council of Ministers.

B. DEVELOPMENT OF INSTRUMENTAL EQUIPMENT

1. Leveling Instruments

Presumably the leveling instruments first used for leveling of any great pretense to precision were of foreign manufacture. Rabinovich (1) refers to Wolfram's level in connection with the leveling from 1875 to 1877. Yeliseyev (3) states that West European manufacturers of geodetic instruments were very much interested in the preservation of a market for their instruments in Russia, jealously guarded their production secrets, and closed their doors to Russian scientists. The Russians, in turn, began the development of their own production for the manufacture of various sorts of geodetic equipment. In 1948 the only major item being imported was invar.

From a study of Krasovskiy's textbook (4) it appears that the leveling instrument in use in the U.S.S.R. in 1939 and illustrated on page 337 (Fig. 333) is essentially a "wye" level in its general features, although equipped with a micrometer screw for the final control of the main bubble. This level became standard about 1935 and is claimed to have superseded the instrument pictures on page 336 (4) which was in prior use, a rather similar instrument.

The instrument in use after 1935 appears to have a magnification of 36X to 40X, a focal length of the telescope of about 40 cm., and an objective about 40 mm., in diameter. This makes the instrument roughly comparable in size to the Coast and Geodetic Survey type level, although the sensitivity of the bubble in the Soviet level is apparently about 5" per division while the C. & G. S. level is sensitive to 2" per division.

An instrument catalog (8) published in 1949 shows a rather complete line of Soviet-made leveling instruments. The specifications and other characteristics of the various levels illustrated in this reference have been assembled in tabular form as shown below:

Specification or Characteristic	Designation				
	NPG	NA-1	NT	NG	Light Mountain
"Wye" or "Dumpy" type	Dumpy	Dumpy	Wye	Dumpy	Wye
Equipped with plane-parallel glass	Yes	Yes	No	No	No
Prisms or mirror for viewing bubble	Prisms	Prisms	Mirror	Prisms	Neither
Bubble image in field of view	Yes	Yes	No	No	No
Diameter of objective	55 mm	55 mm	34 mm	34 mm	36 mm
Magnification of telescope	44X	44X	32X	31X	30X
Focal length of telescope	410 mm	411 mm	314 mm	314 mm	316X
Stadia constant	100	100	100	100	100
Field of View - horizontal	40'	40'	60'	60'	90'
Field of View - vertical	60'	60'	60'	60'	90'
Will focus from — to ∞	3.5 m	3.6 m	3 m	3 m	?

Specification or Characteristic	Designation				
	NPG	NA-1	NT	NG	Light Mountain
Main bubble, value of 2 mm division	10"	10"	17"-25"	25"	20"±2"
Circular level, value of 2 mm division	10'*	2'	7'-15'	7'-15'	?
Magnification of viewing device for main bubble	2.6X	?	None	?	None
Weight of instrument	5.5 kg.	5.8 kg.	2.45 kg.	2.25 kg.	[illegible].7 kg.**
Weight of tripod	6.5 kg.	?	?	4.0 kg.	[illegible].[illegible] kg.

* This entry seems to be a blunder. Probably should be 1' instead of 10'. It could hardly be 10".

** It seems peculiar that the light mountain level should be heaver than both the NT and NG models.

No rods are listed or described in this catalog. However, it would seem reasonable to <u>assume</u> that, since the leveling instruments have been greatly improved since 1939 (the date of Krasovskiy's text book) the rods might also have been similarly improved since that time.

2. Rods

Little material seems to be available concerning the rods used on the earlier leveling. However, Krasovskiy (4) shows a diagram of a portion of the face of the type of leveling rod used at the time that book was written (1939) and the essential features of the rod are as follows:

Cross-section about 4 x 6 cm.

Length 3 m.

Graduations are fine-line graduations at 5 mm. intervals flanked by alternate black and while centimeter spaces on the face of the rod. The back of the rod has fine-line graduations at 5.5 mm. intervals flanked by alternate rod and while spaces 11/10 cm. wide. An unusual feature of these rods is not the fact that they are paired but the fact the rod of each pair bearing the odd number has the zero of the graduations on the black side set 10 cm. farther up from the actual physical foot of the rod than the zero of the graduations on the black side of the rod bearing the even number. The zeros of the red graduations remain at equal distances from the actual physical foot of the rod. Additional information concerning this peculiarity in the rods will be found under the heading, "Field Methods." (See Section D)

A spot or circular level is placed on the rod to insure accurate plumbing of the rod when in use.

Graduations are apparently painted directly on the wooden rod. At the 0.5, 1.5, and 2.5 m. marks on these rods there is inserted a small metal plug bearing fine lines in the form of a plus sign. These are evidently the standardization marks, the relative positions of which are checked by means of the scale discussed below.

It is difficult to understand why such inferior types of rods were tolerated in attempting First- and/or Second-order leveling.

In an attempt to overcome this deficiency the Russians apparently used an accurately graduated scale, equipped with a magnifier, for frequent checking of the rods in the field. While this may serve to correct the deficiency of having the graduations directly on the wooden rod, it makes much extra work in the field checking of the rods and must complicate the field and office computations seriously.

3. Auxiliary Equipment

Krasovskiy (4) shows a picture of an elaborate foot plate having a weight of 5 kg. (about 11 or 12 lbs.), having three feet, a carrying handle, and two round-topped projections from the upper surface on which the rod is placed for use. These projections are of different lengths, apparently providing for the "double rodding" of a line if desired.

Other references in available literature speak of "turning pins". This would seem to indicate that the foot plate is not always used.

Thermometers are carried by the observing parties but the rods do not seem to have thermometers imbedded in them as is the case with the rods in use by the U.S. Coast Geodetic Survey.

4. Datums

The leveling net of the U.S.S.R. has developed gradually during the period from 1847 to date and much of the early work has, of course, been repeated in an effort to increase accuracy. Very little if any of the leveling prior to 1917 was of sufficient accuracy to be useful in connection with the later plans for the development of the leveling net of the U.S.S.R.

There seem to have been at least four fundamental "zeros" in use up to the present time and, of course, an unknown number of less important or supplementary datums for use more or less temporarily.

The zero of the gage at Kronshtadt seems to be the first and most important datum. Whether or not this means the actual physical "O" graduation of the tide gage at Kronshtadt or mean sea level at Kronshtadt is somewhat in doubt. Presumably, mean sea level at Kronshtadt is the "zero" for this datum but the doubt arises in a reference by Pavlov (5) where the following information is given. It was established that:

1. The Baltic Sea is 1.873 m. higher than the Pacific Ocean, and

2. The zero of Kronshtadt's tide gage is 1.986 m. higher than the one in Vladivostok.

On the other hand, we would have to assume that mean sea level at Kronshtadt would be the logical surface to use as a zero of elevations. In any event the difference is 1.986 m. minus 1.873 m. = 0.093 m. This is not too serious as a possible doubt on absolute elevations even if we assume it all to be a doubt as to the Kronshtadt datum.

The reference (5) gives the further information that for leveling in the Caucasus the level of the Black Sea was accepted as the initial height in accordance with observations at Poti, Novorossiysk, and Taganrog. (See Vremennyy Katalog vysot marok Kavkazskoy nivelirnoy set, 1884-1915 gg. -- "Preliminary Catalog of Markers of the Caucasus Leveling Net 1884-1915") (9)

Up to 1907, for leveling in the Middle-Asia region the zero of the barometer of the Tashkent Astronomical and Physical Observatory was accepted as the datum. By 1910 this Observatory had been connected by spirit leveling to the mean levels of both the Baltic and Black Seas. In 1930 a new adjustment of the Middle-Asia leveling was made by the Military-Topographic Section of Middle-Asia and the zero of the Kronshtadt tide gage was accepted as the initial height.

The First Geodetic Conference of the Gosplan (April 19 - 22, 1926) decided to compute all elevations from the zero of Kronshtadt's tide gage. This action was confirmed by the Second Geodetic Conference of the Gosplan (April 11 - 14, 1927).

In 1937 the GUGK ordered that all elevations in the territory to the east of Krasnoyarsk be transferred to the level of the Pacific Ocean. Presumably this infers mean sea level at Vladivostok.

For leveling in Western Belorussia and Western Ukraine elevations were referred to the level of "the Northern Sea" and these elevations vary from those of the Catalog of 1934 by 15 cm. The algebraic sign of this 15 cm. difference is not apparent from material at hand.

Elevations in the territory received from Finland in 1940 were based on the mean level of the Baltic at Napdo as an initial or zero height.

Elevations in Lithuanian SSR, Latvian SSR, Estonian SSR, Bessarabia and Northern Bukovina were not in agreement with the datum used in the Catalog of 1934. Material at hand does not give information as to numerical size or algebraic sign of any of these datum differences.

C. SOVIET INSTRUCTIONS FOR GENERAL ADJUSTMENT

1. General Provisions

The need for bringing order out of chaos regarding the various systems of leveling must have long been recognized by the Soviets. A reference (6) in 1948 is entitled, "Basic Instructions for General Adjustment of the Leveling Net of the USSR." This document goes into very great detail but the essential features are about as follows: (Numbers refer to sections of the original document as translated.)

1. General adjustment is needed to establish a unified system of elevations.

2. In accordance with the resolution of the Council of Ministers of the U.S.S.R., (No. 760 of April 7, 1946) the zero of Kronshtadt's tide gage must be the initial point for the adjustable portions of the basic leveling net.

3. Orthometric corrections must be applied.

4. Adjustment to include leveling of first-order and second-order accuracy.

5. The entire basic leveling net of the U.S.S.R. is (for adjustment purposes) to be divided into three parts:

a. The first part includes all leveling west of the leveling line from Kronshtadt, via Leningrad and Moscow, to Sevastopol'. This leveling is not to be included in the adjustment because of the necessity for re-leveling many lines along which the bench marks were damaged or destroyed during World War II.

b. The second part includes the leveling eastward of the leveling from Kronshtadt, via Leningrad and Moscow, to Sevastopol'. This includes the major portion of the European part of the U.S.S.R., the Caucasus, Western Siberia, Kazakhstan and Middle-Asia. This leveling must be adjusted in accordance with these instructions (6).

c. The third part includes leveling eastward of Novosibirsk in the territory of Eastern Siberia and the Far East. Because this portion of the net is connected with part two only by the one line of levels along the Siberian Railway, this portion of the net must be adjusted after the leveling included in the second part.

Also, leveling in the district of Kolyma, which (1948) had not been connected with the general net was to form a special case and be treated separately.

6. In selecting lines for inclusion in the general adjustment, not only the quality of the leveling but also the value of the line to the rigid framework was to be considered.

7. The general adjustment to be accomplished by the method of least squares.

8. The weights assigned to the various lines and/or links in the net were to correspond to the accuracy of the individual lines involved.

9. After adjustment the weights assigned for the adjustment were to be reviewed and, if necessary, new weights were to be assigned and a readjustment made. (Note: This has some of the ear marks of "tinkering" to make the results come out the way you want them to.)

10. The general adjustment was to be carried out by the Central Computation Department of the CUGK. Decisions necessary during the progress of the work to be passed on by the TsNIIGAiK (Central Scientific Research Institute of Geodesy, Aerial Surveying, and Cartography).

11. All computations to be done in duplicate, each computer working independently. Also such other checks as control sums, etc., were to be applied whenever and wherever possible.

12. Computations to be made in the classical order, on good paper, in India ink, and legibly.

13. For convenience during future use, computations were to be carefully systematized, arranged in logical order, indexed, and accompanied by a complete explanation of the chronology of the work, names of computers, checkers, etc. The finished computations were to be bound in standard covers and inventoried.

14. First- and second-order leveling within the loops or circuits of, but not included in, the general adjustment was to be fitted to the adjusted frame work after the general adjustment had been finished.

15. As a preliminary to all of the above, a progress sketch or index map was to be produced, at a scale of 1:?,500,000, for reference during and after the adjustment.

2. Preparatory Work

16. Central Computation Section to gather, systematize, and analyse the data concerning the leveling to be included in the general adjustment.

17. Each line of levels must be evaluated separately to determine whether or not the accuracy actually attained was within specified tolerances. Formulae for use in these evaluations are prescribed.

18. Provision is made for taking mean differences at or near junctions where check leveling was run in starting or trying out new projects.

19. Provides for the rejection of leveling prior to 1917 and later leveling of doubtful accuracy resulting from movement of bench marks.

20. Provides for the computation and application of orthometric corrections prior to computation of circuit closures. Also refers to Supplement No. 2 of the instructions in cases where gravity anomalies require special computation of orthometric corrections by other than the usual general formulas. Also provides for taking into account the "gravity of the relief" in high-mountain areas.

21. Provides for preparation of tables of differences of elevation or closures for the various lines, loops, and polygons. (Note: The distinction between a loop and a polygon is not clear. In our terminology we refer to lines, links, and circuits. However, to try and match loops and links involves difficulties.)

3. Evaluation of Precision of Results

22. For the evaluation of the precision of the leveling, lines are divided into possibly six groups. Assignment of a particular line to a specific group to depend on some or all of the following considerations:

A. Class or degree of the leveling,

B. Performance of field work under same instructions,

C. Similar field methods,

D. Similarity of meteorological conditions; if necessary, pay attention to temperature gradients, using the schematic map of zones of equal temperature gradients in Supplement No. 3,

E. Approximate general direction of line,

F. Conclusions from inspections, documents of OTK (Office of Technical Control), etc.,

G. The organization of the lines into appropriate groupings will be checked with the TsNIIGAiK.

23. Gives elaborate formulas for the computation of systematic and accidental errors. Errors to be computed for each group to which lines have been assigned. All this according to Soviet theory and practice.

24. Gives similar formulas proposed by the International Union of Geodesy and Geophysics in order that results may be compared with those obtained in other countries.

25. Provides for drawing for each line a graph on which distance along the line is plotted along the X axis and accumulated divergences between forward and backward runnings is plotted against the Y axis. (Note: This appears to be exactly the equivalent of a graphical showing of what we call the "accumulated B-F" or "accumulated partial.")

4. Adjustment Computations

26. After the orthometric corrections have been computed and applied, the discrepancies of the polygons are computed. (Note: This is the same

as computing circuit closures in our terminology or in British terminology the "misclosures" of the loops or circuits.)

27. During the first adjustment of basic polygons (circuits) the net is supposed to be free and corrections ("Vs") are computed for lines or links of uniform accuracy. However, if the leveling along any one link (the leveling between two adjacent junction points) is not of the same character or accuracy the link is broken up into lines or pieces of lines according to accuracy, method, class, etc., and a "V" or correction is computed for each component part of the link.

28 & 29. Provide for computations to obtain the weights to be assigned to each link or line which is to take a correction as a result of the adjustment. Formulas for these computations are given.

30. After the formation of the condition equations and the computation of the weights, (the results in tabular form would be our "table of correlates") "normal correlate" equations (normal equations, in our terminology) are formed. The numerical solution of this system of equations results in a series of factors for use in the computation of the Vs or corrections to the lines and/or links and when these are computed and applied the various circuits should close perfectly.

31. Inspection or investigation of suspicious cases may result in the necessity for changes in some previously assigned weights. If this be done a new computation must be made. Such action must be authorized by the TsNIIGAiK and decisions must be approved by the GUGK.

32. Corrections resulting from the final adjustment are distributed uniformly along the links and/or lines in proportion to distances of the individual bench marks along the line to arrive at their adjusted elevations.

33. Corrections are to be studied, with the TsNIIGAiK participating, to determine the effect of various factors or conditions on leveling results and findings of this analysis are to be used as a basis for the study of possible changes in organization and/or methods for the execution of precision leveling.

34. Provides for the computation of the mean-square error of certain marks or groups of marks located in various parts of the net.

5. Compilation of Catalogs and Scientific-Technical Reports

35. Provides for the compilation of a catalog of the adjusted leveling, according to prescribed rules. (Note: This catalog is apparently the equivalent of our "lists of bench mark descriptions and elevations.")

36. Provides for the preparation of the scientific-technical report. (This report appears to be aimed at including information on what work was done, quality of resulting elevations, weights assigned during the adjustment, the tables of equations, statements concerning the datum at Kronshtadt, and the uses to which results should be put in handling additional leveling. (Note: Much of this material appears to be duplication of what has already developed during the course of the adjustment computations).

Supplement 2 to the above-mentioned instructions provides methods and formulas for the computation of orthometric corrections in regions or areas where gravity anomalies are sufficiently large and accurately enough determined to warrant the extra refinement in the computations.

6. Additional Instructions

Certain additional provisions for complying with the terms of Resolution No. 760, of April 7, 1946 appear to come from the same source as the above (6). They may be abstracted as follows:

The general adjustment should include all acceptable leveling up to 1946 and from then on all new leveling must be based on the resulting unified system of elevations.

All new leveling is to be computed in the offices of the institutions which carry on the field work.

All topographic maps and catalogs issued, beginning with 1946, must carry statements concerning the system of altitudes or coordinates used.

In order to prepare leveling of the I or II class for inclusion in the general adjustment, new lines necessary in former occupied territory must be completed by 1948.

Any leveling done from 1876 to 1917 must be completely releveled before being included in the basic net work. Leveling done from 1936 to 1941 must be releveled only as may be necessary to reestablish destroyed bench marks.

In other cases leveling shall be admitted to the basic net if found to be of sufficient quality or when parts deficient in quality are releveled to bring them up to the proper accuracy standards.

D. SOVIET FIELD METHODS

Spirit leveling in the U.S.S.R. is classified, according to methods used and accuracies specified, as First-class, Second-class, - - - to Fifth Class.

The accuracy tolerances, as well as they can be tabulated from the material at hand, are as follows: (1)

Class or Order of the Leveling	Permissible Error (mm. per km.)	
	Systematic	Accidental
First	± 0.2	± 1.0
Second	± 0.4	± 2.0
Third	± 0.8	± 4.0
Fourth	± 2.0	±10.0
Fifth	--	--

Computed by means of the international formulas (Presumably those of the International Union of Geodesy and Geophysics.)

The spirit leveling is, as might be expected, run in closed loops or in continuous lines between previously established marks. Permissible loop perimeters or lengths of lines between tie points, for the various classes of leveling are:

Class or Order of the Leveling	Allowable Circuit or Line Length (km.)
First	600 - 1200
Second	500 - 600
Third	200
Fourth	100
Fifth	---

Third-class leveling is specified for use along traverse lines for determining grade or slope corrections to lengths measured with tapes, which are not kept horizontal during the measurements.

It will be noticed that no entries appear in the two tables given above for Fifth-class leveling. Specifications were not available in the material at hand, but it is probable that this class includes any form of leveling of sufficient accuracy for local control of topographic work and that the limits of accuracy may be flexible and depend on the scale of the map to be made, the contout interval, and the degree of remoteness from any previously established control of the area to be surveyed.

Leveling lines of both First- and Second-class accuracies are apparently run in both directions. This may be readily inferred from the fact that if the Second-class leveling was run only in one direction it would be impossible to compute the accidental and systematic errors by means of the prescribed formulas. Whether or not the leveling of classes of accuracy lower than the second are run in both directions is not clear. Probably they are not, except perhaps under special conditions or on spur lines.

Up to 1939 no evidence appears in the material at hand that the Russians made use of a plane-parallel glass in front of the objective lens, as in the Wild, Zeiss, and other levels now on the market.

Their observing routine was quite elaborate and may be stated as follows:

Each pointing or rod reading requires the following observations and entries:

1. Read and record the position of both ends of the bubble,
2. Read and record the positions of the three horizontal wires as seen on the rod, and
3. Read and record the position of both ends of the bubble.

Each setup or instrument station requires four pointings or rod readings, each made according to the above-outlined procedure, and in the following order:

1. Read the black side of the back rod,

2. Read the black side of the forward rod,

3. Read the red side of the forward rod, and

4. Read the red side of the back rod.

Also, between the completion of the second pointing and before beginning the third pointing the tripod is tapped smartly enough to cause a slight movement of the bubble along the tube.

The black side of the leveling rod is graduated in meters, decimeters, and centimeters and the wire readings are made by estimation to the nearest millimeter in each case. Corrected mean readings are carried out to tenths of millimeters.

The red side of the leveling rod is graduated in units of 10% greater size than those on the black side. Thus, a reading or a difference observed on the red graduations must be increased by 10% to correspond to the same reading or difference observed on the black graduations. This situation is further complicated by the fact that, as pointed out under "Development of Instrumental Equipment" (B) the zero of the black graduations on the odd-numbered rod of each pair is set 10 cm. further above the actual physical foot of the rod than are the zeros of the red sides and the other black side.

In the field, the check on the readings is attained by setting down the difference of the mean readings (red side) for the backsight and foresight at any one setup, increasing that by 10%, then correcting by 100.0 mm., and comparing the result with the directly determined difference of the mean readings on the black side.

Now, if the rods are allowed to remain each on its own turning point, the arbitrary 100.0 mm., introduced by the arbitrary dislocation of one of the black zeros from its normal position, balances out at the end of every even numbered setup along the line. However, a section run on the black and having an odd number of setups will require an arbitrary correction of 100.0 mm.

The fact, that at some time between 1939 and 1949 instruments having plane-parallel glasses in front of the objective lenses were brought into use, has probably had a marked effect on the details of the observing routine. We cannot learn, from the material at hand, what changes (if any) have been made.

E. BENCH MARKS

Bench marks are, of course, set to preserve the elevations determined. Apparently the marks are not set as frequently along their lines of levels as is the case in the United States of America. In the U.S.S.R. the minimum distance between bench marks seems to be from 1 to 2 km., with the maximum distance running up to 10 km. or more. On the other hand, in the U.S.A. the average distance between bench marks must be one mile or less and the maximum distance in difficult cases only about double the average distance.

The character of bench marks in the U.S.S.R. seems to run about the same as in the U.S.A., except that the Russians provide (theoretically, at least) for more of the elaborate type of mark which might be called a fundamental bench mark and which has both a surface and underground mark. The Corps of Engineers, U.S. Army, used and may still use what were known as "pipe-stone" marks in the Mississippi and Missouri Valleys. These would be the nearest American approach to the elaborate affair provided for in the U.S.S.R., except for those used in Canada and which resemble more closely those of the Russians.

Metal tablets of the same general character as those used in the U.S.A. are used quite generally in the U.S.S.R. The chief differences are, of course, in the inscriptions and the design of the shanks. The shanks of the Soviet tablets apparently require lathe work during production while in the U.S.A. the design of the shanks of the various tablets is such that no lathe work is required in bringing the shanks to their final shapes. However, the Russian marks, after they have been set, would look rather like the similar marks in the U.S.A. except for the language used in the inscriptions or legends which are cast in or stamped on them.

F. TRIGONOMETRICAL LEVELING

In the Soviet literature at hand, the term for what we in the U.S.A. call trigronometrical or vertical-angle leveling is "geodetic leveling." This may cause confusion because in the U.S.A. there is a growing tendency to refer to spirit leveling of First-, Second-, and sometimes Third-order accuracy as "geodetic leveling" while the same sort of leveling in Russia is called "geometrical leveling."

In the U.S.S.R. elevations are carried through the triangulation schemes and along traverses by means of vertical-angle leveling, though they do not claim to attain any unusual accuracy in this work. Errors as large as 1 meter may occur in triangulation lines as short as 10 km.

Elevations determined by vertical-angle leveling are not as a rule published in the catalogs of bench marks whose elevations are determined by means of spirit leveling but are included in the publications giving the results of the triangulation.

G. BAROMETRIC LEVELING

In isolated regions at great distances from previously established vertical control, barometric leveling must be depended on for the establishment of temporary datums and for local control in the production of small scale maps. Even fairly long series of barometric observations cannot be depended on to give accuracies much better than vertical-angle leveling. Barometric leveling is a sort of "court of last resort" when conditions are such that nothing better is or can be made available at the time.

APPENDIX I

GENERAL STATUS OF LEVELING IN THE U.S.S.R.

A. GENERAL STATEMENT

The general status of Soviet leveling of first and second class is described in source (2) of 1945, which contains a definite statement of the status of 1944. Another source dated 1948 (1) also contains a map showing the status of leveling. One might quite naturally assume that this latter would refer to the date of publication but, as a matter of fact, the contents of the two maps are identical.

The map which was published in source (2) is reproduced as Figure 1 of this report. It is supposed to indicate the work carried out by the

GUGK - First-class and second-class leveling

VTU - Second-class leveling

Other agencies - Second class

Analysis of this map is difficult because of the density of leveling lines in the European U.S.S.R. area and because the scale of the map is so small. However, some general conclusions may be formulated from inspection of the map:

(a) The first class levelling is done only by the GUGK. This circumstance can be established from the map in source (1) where first-class leveling lines are more clearly distinguished than they are on source (2).

Leveling performed outside of the boundaries of the European part of the Union up to 1944 had apparently been restricted to lines along the following railroads:

Vladivostok - Khabarovsk

Irkutsk - Chelyabinsk

Chkalov - Tashkent

Tashkent - Mary

(b) "The other agencies" besides the GUGK and the VTU account for only a small fraction of second-class leveling, scarcely exceeding 1,000 kilometers. The following sections done by these agencies may be identified as:

Magadan - Kolyma River

Northern portions of the Ural Mountains

Short Line north of the Crimea

The first line, along a route between Magadan and the Kolyma River is in a region of concentration camps and this leveling was probably carried out by the Dalstroy; that is, by the Administration of Corrective Labor Camps. It is also interesting to note that this leveling was extended by the GUGK westward to the Indigirka. It is possible that a similar explanation may be applied to the Northern Ural leveling.

At any rate, it is clear that of the total 127, 550 kilometers of first- and second-class leveling, at least 115,950 kilometers can be definitely assigned to work by the GUGK and at least 10,000 kilometers of the remainder, to the VTU.

(c) Of the second-class leveling in the Asiatic part of the Union, the following links are especially interesting:

Krasnoyarsk - Estuary of the Yenisey River, along the Yenisey

Tayshet - Yakutsk, along the Lena River

Skovrodono, on the Siberian railroad to Yakutsk

Khabarovsk - Nikolayevsk, along the Amur River

Novosibirsk - Alma Ata

Novosibirsk - Ashkhabad

Chelyabinsk - Gur'yev

(d) The fact that leveling is poorly developed in the Asiatic portion of the U.S.S.R. is very striking. Up to 1944, first-class leveling did not exist there even along the railroads. Northern portions were almost untouched by second-class leveling. One might expect that the Soviets have done something about this situation by this time.

Apparently the Soviets have done just this. Evidence for this statement may be found in the chapter on Geodesy in Volume 10 of the Soviet Encyclopedia, published in 1952, in which it is said that the extent of first and second class in the U.S.S.R. in 1950 was 150,000 kilometers. If we compare these figures with those of 1944, we find that the Soviets in six years have measured about 93,000 kilometers of first- and second-class leveling. This work might well have been done to a great degree in the Asiatic portions of the country where the network is least complete. In all probability all of the main Siberian rivers, the Ob', Lena, Indigirka, Kolyma and Anadyr, in addition to the Yenisey, have been covered by leveling of second class.

B. STATUS OF PRECISE LEVELING IN THE U.S.S.R.

No detailed information on the status of leveling covering all work in the U.S.S.R. has been found. The general statement (2) indicates the following figures for work carried out by the GUGK:

Leveling 1st and 2nd order	1919-1924	1,750 km
	1925-1929	13,500 "
	1930-1934	21,100 "
	1935-1938	26,800 "
	1939-1943	52,800 "
	Total	115,950 km

To these should be added leveling of 1st and 2nd order carried out by other (unspecified) agencies, making the total for the years 1919-1943, 127,550 km.

In the same source few details are given for some of the precision leveling carried out by the GUGK, as follows:

1921-1933

	Link	Year	Errors per 1 km Accidental	Systematic
1.	Gorbachevo-Bogoyavlensk-Yakhontovo	1925	0.4 mm	0.08 mm
2.	Bogoyavlensk-Michurinsk-Platonovka	1928	0.7	0.08
3.	Bogoyavlensk-Ryazan'	1926	0.8	0.12
4.	Penza-Ruzayevka	1927	0.6	0.08
5.	Atkarsk-Penza	1924	0.6	0.10
6.	Debal'tsevo-Zverevo	1929	0.7	0.07
7.	Durasovka-Linevo Ozero	1923	0.5	0.10
8.	Yershov-Urbakh	1924	0.3 mm	0.04 mm

1933-1937

	Link	Year	Length	Errors per 1 km Accidental	Systematic
1.	N. Dobrinka-Zel'man	1933	101 klm	1.12 mm	0.15 mm
2.	Vnukovo-Kaluga	1937	163	1.58	0.13
3.	Tiberda-Sukhumi	1933	150	1.65	0.04
4.	Ulan-Ude-Kyakhta	1937	232	1.28	0.07
5.	Bazhenovo-Yalutorovsk	1934-	191	1.00	0.12
		-1935	154	1.23	0.12
6.	Barnaul-Kamen'	1937	212	1.18	0.07
7.	Barnaul-Pokot'	1933	213	1.08	0.12
				1.55	0.12
8.	Vapnyarka-Peregonovka	1935	293	1.43	0.03
				1.21	-
				1.10	0.06
				2.70	-

	Link	Year	Length	Errors per 1 km Accidental	Systematic
9.	Zelenchuk-Sukhumi	1933	343 klm	1.45 mm	0.10 mm
				1.57	0.34
10.	Kamyshin-Nikolayevka	1933	-	0.62	0.09
11.	Kulunda-Pevlodar	1933	138	1.07	0.02
12.	Sharzhash-Kurgan	1933	361	0.70	0.03
13.	Lokat'-Semipalatinsk	1933	121	1.55	0.12
14.	Buzuluk-Andreyevka	1934	62	1.43	0.01
				1.88	0.20
15.	Pleshkino-Kotlas	1936	13	1.60	0.05
16.	Sukhona-Pleshkino	1936	555	1.45	-
				1.25	0.17
				1.36	0.13
				1.95	0.06
17.	Cherepovets-Rybinsk	1933	219 klm	1.42 mm	0.33 mm

High Precision Leveling in 1937

	Link	Length	Errors per 1 km Accidental	Systematic
1.	Orsha-Vyaz'ma	294 klm	1.00 mm	0.18 mm
2.	Vyaz'ma-Odintsovo	233	1.12	0.10
3.	Bryansk-Khar'kov	467	1.2	0.35
4.	Svyatogorskaya-Khatseperovka	172	1.07	0.20
5.	Moskva-Ryazan'	198	1.31	0.12
6.	Rostov-Taganrog	76	1.23	0.23
7.	Likhaya-Aksay	140	0.95	0.48
8.	Stalingrad-Ilovlaya	84	0.79	0.12
9.	Kirovabad-Baku	368	0.82	0.10
10.	Kirovabad-Gori	273	1.04	0.05
11.	Gori-Batumi	271	0.93	0.11
12.	Minusinsk-Kandoma	358	1.60	0.14
13.	Bureya-Svobodnyy	227	0.66	0.09
14.	Bureya-Esaulovka	157	1.11	0.23
15.	Esaulovka-Birobidzhan	163	1.10	0.13
16.	Birobidzhan-Khabarovsk	192	0.99	0.10
17.	Gudermez-Alyat	435	0.83	0.14
			0.97	0.04
18.	Alyat-Evlakh	210	0.82	0.10
19.	Samtredi-Batumskiy port	106	0.93	0.11
20.	Trusovo-Vyshka	122	0.69	0.09
21.	Evlakh-Mtskhet	283	0.82	0.10
			1.04	0.05
22.	Likhaya-Stalingrad	402	0.95	0.17
23.	Mtskhet-Samtredi	56	1.04	0.05
24.	Sankovo-Rybinsk	106	0.30	0.04
25.	Dosnag-Gur'yev	400 klm	1.00 mm	0.02 mm

Leveling done by the Moscow
Aero-Geodetic Establishment, 1938-1940

	Link	Year	Length	Errors per 1 km Accidental	Errors per 1 km Systematic
1.	Ul'yanovsk-Sviyazksk	1938	192 klm	0.90 mm	0.20 mm
2.	Smyshlyayevka-Chasovnya	1938	358		
	1st section	1938	60	0.93	0.31
	2nd section	1938	44	1.16	0.32
	3rd section	1938	34	0.88	0.08
	4th section	1938	42	0.80	0.02
	5th section	1938	78	0.94	0.04
3.	Rozhdestveno-Perevoloki	1939	117	0.88	0.24
4.	Kuybyshev-Batraki	1939	152	0.87	0.08
5.	Novosemeykino-Kr. Glinka	1939	44	1.06	0.03
6.	Smyshlyayevka-Kuybyshev	1939	37	1.07	0.21
7.	Rybinsk- Gor'kiy	1939	550		
	1st section	1939	80	0.67	0.17
	2nd section	1939	74	1.22	0.31
	3rd section	1939	178	1.24	0.07
	4th section	1939	117	1.21	0.37
8.	Gor'kiy-Cheboksary	1940	308	0.91	0.15
9.	Sokol'yi-Gory-Pichkasy	1939			
	1st section	1939	60	0.80	0.09
	2nd section	1939	180	0.71	0.06
	3rd section	1939	44	1.15	0.14
10.	Sokol'yi-Gory-Kukmor	1939	147	0.78	0.10
11.	Orsha-Stolbtsy	1940	312	1.04	0.27
12.	Polotsk-Prozorovki	1940	55	1.08	0.02
13.	Likhoslavl'-Bryansk	1940	528	0.97	0.20
14.	Cheboksary-Sviazhsk	1940	124	0.90	0.10
15.	Kuybyshev-B. Glushitsa	1938	115	1.92	0.33
16.	B. Glushitsa-Konstantinovka	1938	28	1.60	0.15
17.	Konstantinovka-B. Tavolzhanka	1938	94	1.32	0.00
18.	Ivanteyevka-Dmitriyevka	1938	85	1.48	0.24
19.	Puyachevsk-Mayanga	1938	116	1.10	0.10
20.	Aleksandrov-Mokrous	1938	64	1.40	0.22
21.	Yershov-Novoretskoye	1938	39	2.20	0.54
22.	Novoretskoye-Novouzensk	1938	91	1.40	0.19
23.	Novoretskoye-Krasnyy Kut	1938	141	1.60	0.29
24.	Kras. Kut-Kochetnaya	1938	77	1.34	0.36
25.	Malouzensk-Laplasovka	1938	111	1.81	0.24
26.	Vasil'yevskoye-Tatartsevo	1938	96	1.30	0.05
27.	Mayanga-Lipovka	1939	47	1.12	0.06
28.	Pugachevsk-Goryainovka	1939	60	1.37	0.04
29.	Pugachevsk-Zvezda	1939	173	1.51	0.04
30.	Androsovka-Yablonovnyy Vrag	1939	88	2.08	0.41
31.	Konstantinovka-Chernen	1939	59	1.08	0. 6
32.	Glyshitsa-Andreyevka	1939	120	1.41	0.10
33.	Bezimyannaya-Shtrekeraw	1939	75	0.41	0.18
34.	Sukhoy Ostrog-Kamennaya	1939	40	1.13	0.28

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	Link	Year	Length	Errors per 1 km Accidental	Errors per 1 km Systematic
35.	Mokrous-Borisoglebovka	1939	37 km	1.40 mm	0.29 mm
36.	Stavropol'-Khryashchevaya	1939	64	1.16	0.23
37.	Melekess-Bol'shoy Yar	1938	77	1.06	0.28
38.	Sergiyevsk-Semeykino	1938	108	1.20	0.05
39.	Atkarsk-Vol'sk	1938	269	1.44	0.11
40.	Penza-Petrovsk	1940	100	1.60	0.32
41.	Linevo Ozero-Baratsevka	1940	119	0.99	0.14
42.	Vasil'sursk-Alatyr'	1940	213	1.20	0.14
43.	Ul'yanovsk-Beresovka	1940	216 km	1.20 mm	0.14 mm

APPENDIX II

SOME NOTES CONCERNING SOVIET LEVELING

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A. CLASSES OF LEVELING

There are four classes of leveling used in the U.S.S.R.: spirit leveling, trigonometrical leveling, "physical" (barometric) leveling and mechanical leveling (used for drawing profiles).

Spirit leveling is of five classes:

(1) This class of leveling is of high precision and serves as the basic network on which other classes of spirit leveling depend. Circuits comprised of leveling of this category have a perimeter of 800-1000 kilometers and are usually laid out along railroads, main highways and large rivers.

(2) Second class leveling is usually called "precise leveling", and consists of leveling lines run within the area of first-class circuits. Such lines never exceed 400 kilometers in length.

Approved instructions for leveling of the above two classes require accuracies as follows:

First class - systematic error- 0.2 - 0.3 mm
accidental error- 1.5 mm per kilometer

Second class - systematic error- 0.4 mm
accidental error- 2.0 mm per kilometer

(3) Third class leveling may have a systematic error of 0.6 mm and an accidental error of 2.0 mm per kilometer.

(4) Fourth class leveling may have a systematic error of 1.0 mm and an accidental error of 2.4 mm per kilometer.

(5) There are no fixed limits of error for fifth class leveling.

B. ZERO POINTS

There are four main "zero" points for leveling in the U.S.S.R.:

(1) Mean sea level at the Kronshtadt tide gauge in the Baltic Sea

(2) Mean sea level at the Theodosia (Feodosiya) on the Black Sea

(3) Barometer at the Tashkent Geophysical Observatory

(4) Mean sea level at the Vladivostok tide gauge

Leveling done in the European part of the U.S.S.R. is measured from the Kronshtadt zero point. Because this point is located on Kotlin Island, it is very difficult to measure this point for mainland operations for every leveling line that is run. Therefore, permanent bench marks, carefully measured in reference to Kronshtadt, were established at Oranienbaum and Leningrad.

Elevation at Oranienbaum - 5.4608 m.

Leningrad - 5.372 m.

In 1931 a leveling route was measured between Oranienbaum and Chudovo. So-called "fundamental" bench marks were set along it. Three of these were established as the main bench marks and six were established as check points. High precision leveling measurements in European U.S.S.R. established a difference in sea level between the Black and Baltic Seas to be about 0.4 meters (Baltic Sea level is the higher).

Russian-Swiss methods were used to perform this leveling (back and forward observations). Bench marks were established at six kilometer intervals. At route intersections two bench marks were set either in building walls or on poles.

Instruments used were of the Reichenbach type but made in the Soviet factories, "Geodeziya" and "Geofizika".

The following table illustrates precision of observations and the accuracy of reduction for leveling of first class:

No.	Leveling lines	Distance in km.	Correction over the entire route in mm.	Correction on one km. of the route in mm.
1.	D'etskoye Selo-Vologda	597.3	+ 146.76	+ 0.246
2.	Vologda-Moskva	507.0	+ 108.03	+ 0.213
3.	Moskva-Rzhev	244.2	+ 6.64	+ 0.027
4.	Rzhev-Novosokol'n'iki	274.6	+ 8.17	+ 0.033
5.	Novosokol'n'iki-Dno	176.7	+ 15.69	+ 0.089
6.	Dno-D'etskoye Selo	223.5	+ 24.74	+ 0.111
7.	Moskva-Moskva	18.6	- 1.85	- 0.099
8.	Moskva-Moskva	9.2	+ 0.10	+ 0.011
9.	Moskva-Moskva	7.2	+ 0.35	+ 0.049
10.	Bryansk-Gomel'	282.3	+ 72.19	+ 0.256
11.	Gomel'-Rogachev	111.1	+ 6.01	+ 0.054
12.	Rogachev-Orsha	174.2	+ 12.47	+ 0.072
13.	Orsha-Novosokol'n'iki	235.4	+ 20.86	+ 0.089
14.	Moskva-Tula	194.5	+ 11.32	+ 0.058
15.	Tula-Gorbachevo	83.3	+ 2.90	+ 0.035
16.	Gorbachevo-Orel	110.1	+ 14.84	+ 0.135
17.	Orel-Bryansk	136.7	+ 21.12	+ 0.154
18.	Khar'kov-Darn'itsy	492.1	- 119.08	- 0.242
19.	Darn'itsy-Pl'iski	155.8	- 15.73	- 0.101
20.	Pl'iski-Gomel'	226.6	- 29.49	- 0.130
21.	Moskva-Orekhovo Zuyevo	91.5	+ 7.77	+ 0.085
22.	Orekhovo Zuyevo-Gor'kiy	366.9	+ 80.72	+ 0.220
23.	Gor'kiy-Arzamas	134.9	+ 14.35	+ 0.106
24.	Arzamas-Ruzayevka	232.4	+ 35.87	+ 0.154
25.	Ruzayevka-Ryazan'	422.5	+ 92.37	+ 0.218
26.	Ryazhsk-Ryazan'	117.2	- 10.14	- 0.087
27.	Skopin-Moskva	279.6	+ 42.67	+ 0.153
28.	Ryazhsk-Skopin	46.0	+ 2.48	+ 0.059
29.	Ruzayevka-Penza	139.8	- 2.09	- 0.015
30.	Penza-Rt'ishchevo	151.8	- 2.39	- 0.017
31.	Rt'ishchevo-Rt'ishchevo	4.4	+ 0.02	+ 0.005
32.	Rt'ishchevo-Kozlov	262.1	+ 6.44	+ 0.025
33.	Kozlov-Bogoyavl'ensk	40.4	+ 0.36	+ 0.009
34.	Bogoyavl'ensk-Ryazhsk	55.9	- 0.09	- 0.002
35.	Gorbachevo-Volovo	65.0	- 4.70	- 0.072
36.	Volovo-Bogoyavl'ensk	179.6	- 3.94	- 0.022
37.	Valuyka-Volovo	477.0	+ 108.70	+ 0.228
38.	Rt'ishchevo-Povorino	210.0	- 0.90	- 0.004
39.	Povorino-Valuyki	387.3	- 2.53	- 0.007
40.	Valuyki-Khar'kov	208.5	- 25.38	- 0.124
41.	Ruzayevka-L'ipyagi	704.5	+ 68.54	+ 0.097
42.	L'ipyagi-Urbakh	375.4	+ 21.26	+ 0.057
43.	Urbakh-Krasavka	181.8	+ 5.94	+ 0.033
44.	Krasavka-Rtishchevo	100.6	+ 2.29	+ 0.023

C. CATALOGS

Leveling observations so adjusted have been included in the following catalogs, known to be available in this country:

1. Katalog vysot Russkoy nivelirnoy seti s 1871 po 1893, sostavlennyy S. D. Ryl'ke. (Catalog of the Russian Leveling Network from 1871 to 1893, compiled by S. D. Ryl'ke)

2. Katalog vysot marok i reperov vysokotochnogo nivelirovaniya, ispol'nennogo glavnym geodezicheskim upravleniyem i upravleniyem voyennykh topografov v Yevropeyskoy chasti S S S R s 1875-1932 gg, izdan v 1934 g. O N T I (Catalog of Elevations, Markers and Bench Marks of High Precision Leveling Performed by the Main Geodetic Administration and the Administration of Military Topographers in the European Part of the U.S.S.R. from 1875 to 1932. Printed in 1934 by O N T I.

   This catalog contains observations for 236 leveling polygons and leveling lines of which 66 are of the most precise type.

3. Pervoye dopolneniye k katalogii vysot marok i reperov vysokotochnogo i tochnogo nivelirovaniya ispol'nennogo glavnym geodezicheskim upravleniyem i upravleniyem voyennykh topografov v Yevropeyskoy chasti S S S R s 1875-1932 g., Izdano O N T I v 1935g. (First Supplement to the Catalog of Elevations, Markers, and Bench Marks of High Precision Leveling Performed by the Main Geodetic Administration and the Administration of Military Topographers in the European Part of the U.S.S.R. from 1875 to 1934. Printed in 1935 by O N T I.

   This catalog contains observations for 30 lines of precise leveling.

4. Svodnyy katalog vysot, marok i reperov nivelirovok raznykh razryadov ispol'nennykh V O T i drugimi organizatsiyami v sredneaziyatskoy chasti S S S R s 1894-1934 g.
(Composite Catalog of Elevations, Markers and Bench Marks of Leveling of Various Classes Performed by the V O T and Other Organizations in the Central Asian Area in 1894-1934).
5. Dopolneniye k vremennomu katalogii sibirskikh nivelirovok 1937 g.
(Supplement to the Provisional Catalog of Leveling in Siberia, 1937)
6. Leveling of the Western Belorussia and Western Ukraine Areas.

D. TRIGONOMETRICAL LEVELING

Trigonometrical leveling is not being used in the Soviet Union at the present time because of its low precision.

E. "PHYSICAL" LEVELING

Physical leveling includes both barometric and hypsometric leveling. Actually in practice they are used simultaneously. Barometric leveling is operational in character and hypsometric leveling is used to acquire supplementary control. Both are used in regions of difficult accessibility, especially in the tayga and tundra areas. In such areas elevations are obtained in these ways at points of recognition in aerial photographs. Such leveling lines are laid out in 1.5 km squares; that is, ready for use with maps on a 1:100,000 scale. Instruments used in such operations include several aneroid barometers, sling thermometers, barograph hypsometers, mercury barometer and a chronometer. Hours fixed for observation are at

7, 10, and 12 A.M. and 3 and 6 P.M., local standard time. The observation period is ten days. Leveling routes may be lines or polygons.

F. MECHANICAL LEVELING (TECHNICAL)

Mechanical leveling is performed by drawing profiles across selected areas. For these purposes special instruments are used: (1) Kharkov level, invented by Leontovskiy,- a pendulum level of complex construction affixed to a bicycle. Deviations of the pendulum from the normal to the earth's surface along measured distances, are drawn on a special graph paper with the elevations indicated to a selected scale. (2) Moskva level, invented by Drobyshev. (3) Level of NKPS, invented by Artanov. Both the Moskva and the NKP level are more complex in construction than the Kharkov level, and both are based on the pendulum principle. (4) Raaben's level. The main part of this level is a mercury level in two tubes and there is an electric elevation meter. This instrument is also fairly complex and is mounted on a bicycle.

All of the above named equipment are of the so-called "automatic" type and were made either at "Geodeziya" or "Geofizika" factories.

G. PROGRESS OF SOVIET ADJUSTMENT OF LEVELING

The Soviets started their over-all adjustment of their leveling network in 1947, using Kronshtadt as the zero point. Their adjustment was divided into three parts.

The first part consisted in adjusting all leveling west of the Kronshtadt-Leningrad-Moskva-Sevastopol' line.

The second part consisted of adjusting all leveling east of the above line, which includes the Caucasus, West Siberia, Kazakhstan and Central Asia.

The third part included all leveling east of Novosibirsk in the Soviet Far East areas.

H. LEVELING ACCURACY

Determination of the accuracy of leveling adjustments are made by using the following formulas:

$$\delta^2 = \frac{[S^2] - [d^2]}{4([\mathcal{L}^2] - [r^2])}$$

$$\eta^2 = \frac{[d^2] - \frac{[r^2]}{[\mathcal{L}^2]} \cdot [S^2]}{4[\mathcal{L}]\left\{1 - \frac{[r^2]}{[\mathcal{L}^2]}\right\}}$$

$$\mathcal{L}^2 = \frac{\frac{[S^2_{\Lambda HH}]}{4[\mathcal{L}]} - \eta^2}{\delta^2},$$

where

δ is the mean systematic error in one kilometer of the route; d (in mm) is the difference between the forward and back observations between two points in the route; r (in km) is the distance between the two points; S (in mm) is the elevation in a distance of the length $\mathcal{L}$ of a line at the forward and back observations: $\mathcal{L}$ is the length of a link along the route where an elevation difference reaches (δ) stipulated by the systematic error at forward and back observations; η is the mean accidental error in one kilometer of the route; and $S_{\Lambda HH}$. (in km) is the elevation difference at the forward and back adjustments of the entire route.

In order to compare the accuracy of Soviet leveling results with those of other countries, the errors δ and η must be computed according to the following formulas:

$$\eta^2 = \frac{1}{4}\left\{\frac{[d^2]}{[\mathcal{L}]} - \frac{[r^2]}{[\mathcal{L}]} \cdot \frac{[S^2]}{[\mathcal{L}]}\right\}$$

$$\delta^2 = \frac{1}{4[\mathcal{L}]} \cdot \left[\frac{S^2}{\mathcal{L}}\right]$$

Weights must be computed by the formula:

$$p_i = \frac{k}{m_i^2},$$

where

p is the weight, k is a constant and m is the total mean error of the observations over the entire route or along a part of it; in which latter case the formula

$$m_i^2 = (\eta^2 + \delta^2 \mathcal{L}^p)\mathcal{L}$$

must be used, where

$\mathcal{L}^p$ (in km) is the length of the section of the route, having a systematic error δ.

The Soviets call this leveling system based on Kronshtadt, the "Baltic" system.

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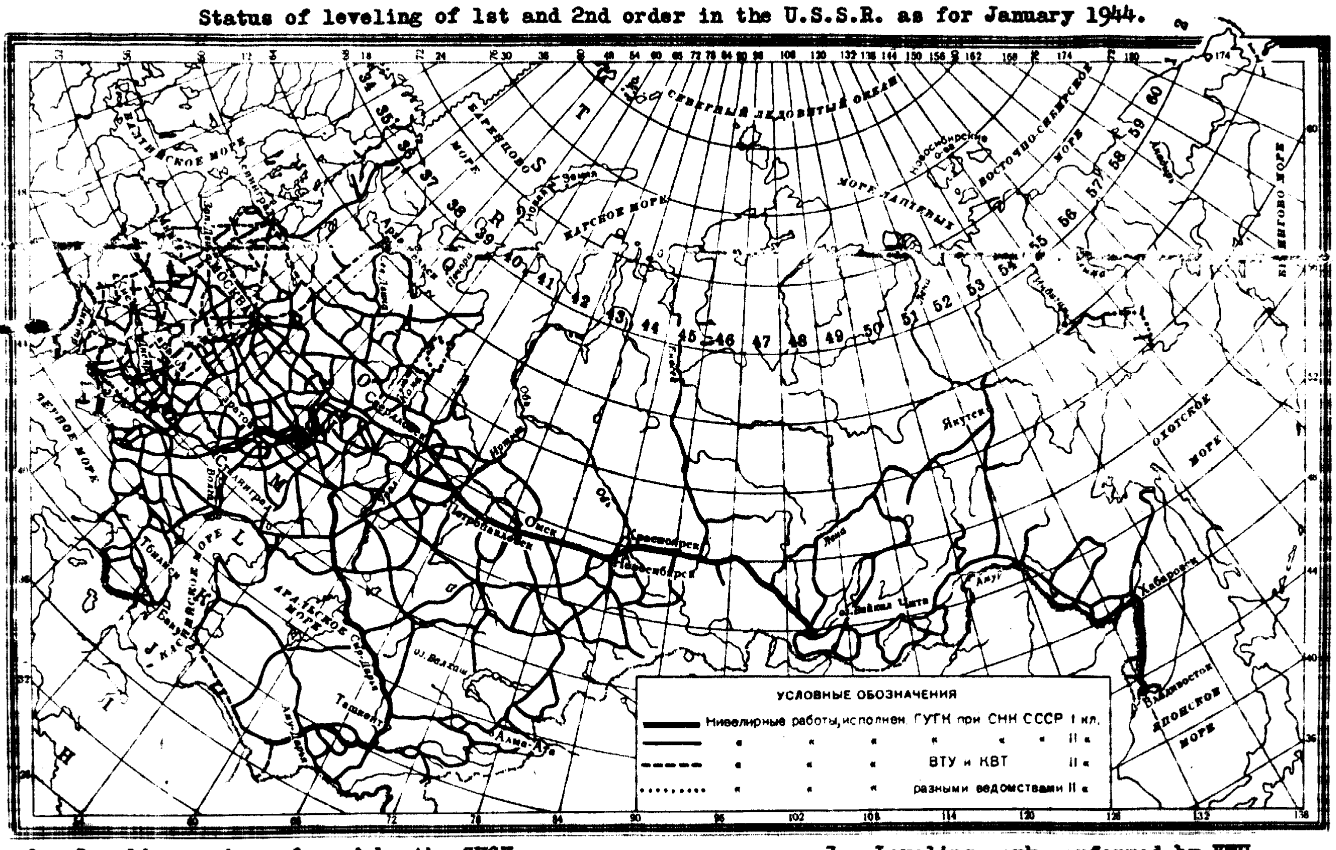
Figure 1

Status of leveling of 1st and 2nd order in the U.S.S.R. as for January 1944.



1. Leveling work performed by the GUGK pri SNK SSSR, first order.
2. Leveling work performed by the GUGK pri SNK SSSR, second order.
3. Leveling work performed by VTU and KVT, second order.
4. Leveling work performed by various departments, second order.